Fire Program Analysis (FPA) System
Preparedness Module

Conceptual Architecture
Final 1.2

June 25, 2003

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Date	Version	Description	Author
6/10/2003	1.0 Draft	Conceptual Architecture deliverable, first cut	Steven Carty
6/23/2003	1.1 Final	Final version submitted for govt. review. Incorporates feedback collected 6/18/2003 with Core Team and Prototype area users.	Steven Carty
6/25/03	1.2 Final	Incorporates feedback collected 6/25/03 with Core Team.	Steven Carty

1 Introduction

The FPA PM system must define an effective initial response organization, considering budgets, resources, expected fires, management objectives, and more. Any number of approaches could achieve this: possibilities include a rules base, simulation, or optimization. The FPA team's selected approach is based on an optimization model that applies constraints, objectives, and resources to a simulated set of likely fires. The team's development of this approach included consideration of the following activities and documents:

1. Developing an Interagency, Landscape-scale Fire Planning Analysis and Budget Tool (the Hubbard Report). This document identifies the need for the FPA system, and recommends an approach to meet that need.
2. Recent and ongoing optimization research in the fire planning arena (ref). This research is an initial step toward addressing the direction given in the Hubbard Report.
3. Analysis of legacy planning systems with respect to the Hubbard Report. These include IIAA99/NFMAS, FirePro, and FireBase.
4. Requirements Specification currently being gathered. The requirements are based on a set of use-cases, which capture the business and technical needs of the system.

1.1 What this document is

The FPA PM Conceptual Architecture (CA) presents the functional and structural "vision" for the system. The CA is a view of the IT and business concepts that will collaborate within the system to meet the requirements. This document presents a view of the planned system, captured at two levels:

- **System Context**: This identifies FPA PM's role, boundaries, and dependencies at the enterprise level. It includes the larger fire planning process and existing agency enterprise systems.
- **System Vision**: This is a view of the IT "concepts" that will collaborate within the system itself to meet the requirements. This view will focus on high-level subsystems and process flows. This view represents the "problem space", that is, *what* is to be done.

1.2 What this document is not

The CA avoids answering *how* we build the system. In general, it will not identify specific solution technologies or components. Looking ahead, the Technical Architecture (TA) will move this vision from IT concepts to the actual solution components. The TA will define the "solution space", that is, how we are to develop the system. The TA (not the CA) will address patterns, mechanisms, physical deployment, web vs. PC-based, administration, browsers, databases, protocols, and other solution specifics like those found in the Federal Enterprise Architecture documents.

2 System Context

The full FPA system will play an important role in the fire planning process. The Preparedness Module focuses on strategic planning for initial attack resources and budgets, as identified in the FPA Project Charter and the RFP. Those documents provide good contextual diagrams, such as the Fire Management Program and FPA Business Function Model graphics. Both identify system boundaries at a high level. The following diagram provides another view of the system context, distinguishing responsibilities that are either in or out of the scope of the FPA PM.

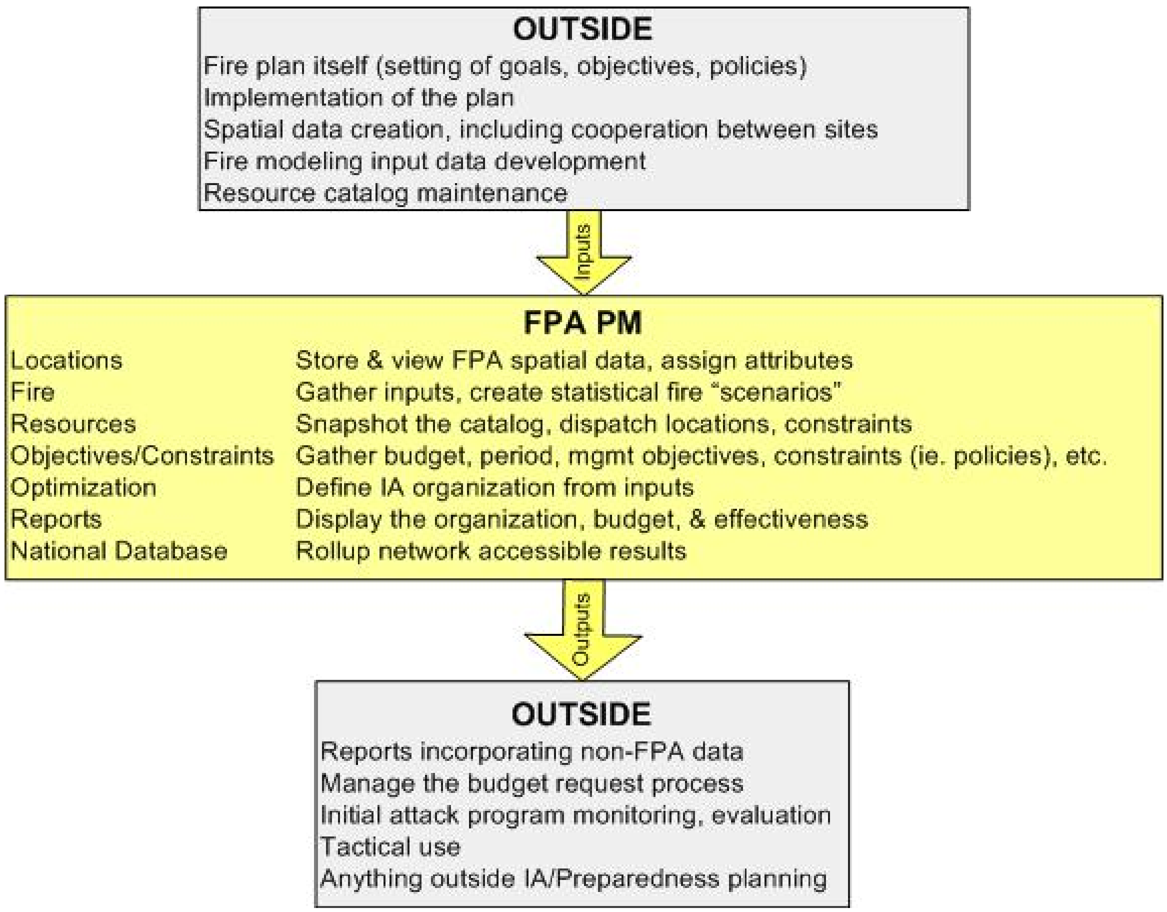


Figure 1 System Boundaries, top-level

This view identifies subsystems within the FPA PM itself, which we will describe in the **System Vision** section. A more detailed itemization of the system's scope is in the FPA PM Requirements Specification (under development).

FPA PM is a tool supporting the budget request process. It does not define the process. This tool will be able to export data and reports to incorporate into the budget request. The FPA PM user documents and help system will identify techniques for getting this data into commonly used formats. The system itself will incorporate (and enforce) business rules as they apply to resource definitions, leadership and support rules bases, and other input parameters. FPA PM documentation will provide guidelines about use of the resulting data, but the system will not enforce policies about use of those outputs. Similarly, the documentation will include guidance on spatial data creation and other external system dependencies.

2.1 External Systems

This inside/outside view defines the system's functionality, and also implies collaboration with existing agency systems. Figure 2 System Context illustrates these legacy system interactions. The actual interaction may be programmatic or manual, to be determined in the Technical Architecture.

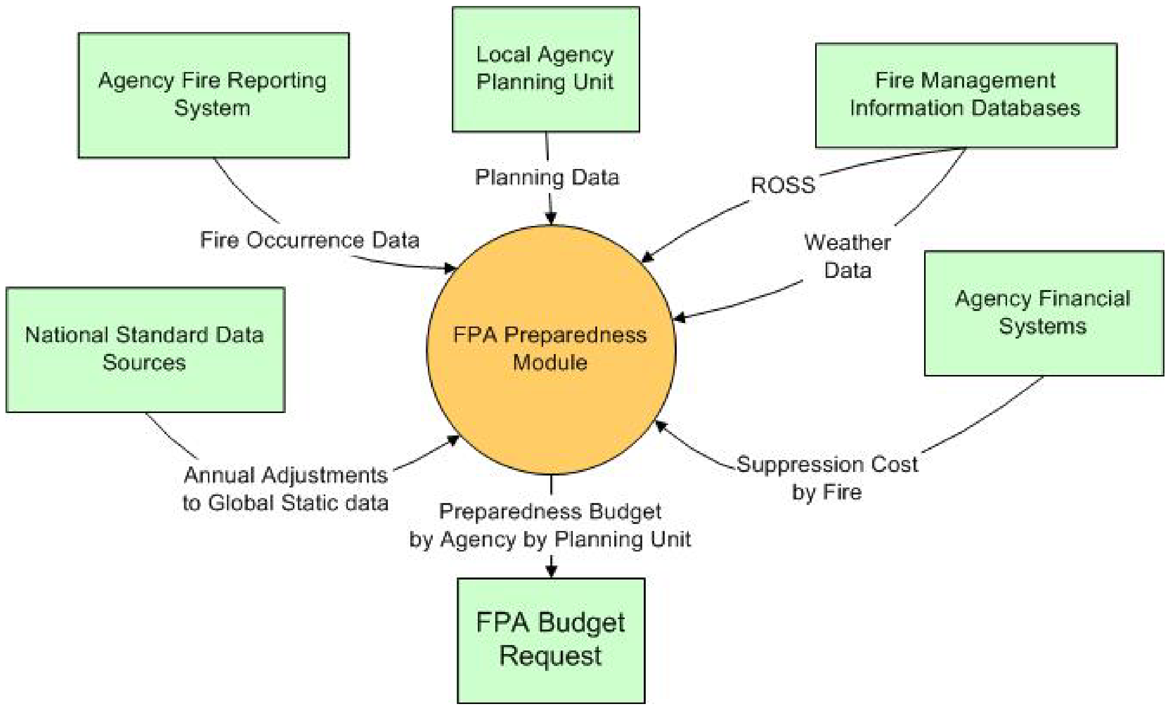


Figure 2 System Context – external systems

A review of agency Service Reference Models (SRMs) and Technical Reference Models (TRMs) will help to identify components that could provide some of these inputs. The FPA PM Technical Architecture (under development) will review those documents and identify the relevant technologies underlying these services. The Federal Enterprise Architecture (FEA) efforts are ongoing, but we can identify potential systems that can fill the FPA PM's needs:

Table 1 Potential External Systems

System	Description	Possible Role
WIMS	Historic weather data	Inputs for the behavior simulation for the fire scenario(s)
1202, NIFMID	Historic fire events	Inputs for frequency of the fires scenario(s)
BEHAVE, Farsite	Behavior simulators	Simulate behavior for the fire scenario(s)
FireFamily+,	Combine weather,	Manage creation of the fire event scenarios. It

PCHA	occurrence, behavior	is possible that the functionality of FF+ or PCHA may be incorporated into the FPA PM system itself.
AFS, FFS	Fire costs	Retrieve escaped fire costs (probably manually retrieved). The optimization model may compute escaped fire costs instead.
ROSS	Fire resource dispatch database	Populate the suppression resource catalog
ESRI COTS tools	GIS	Spatial data creation, editing, display query, and analysis

The Fire and Aviation Management Applications Summary spreadsheet describes most of these (and other associated agency applications) in some detail. The Technical Architecture will resolve which of these systems will collaborate with the FPA PM, and identify the mechanisms supporting that collaboration.

3 System Vision

The FPA PM system will rely on several high level subsystems:

- **Locations**: Captures the spatial definitions of things such as FMU, Workload Points, Dispatch Locations, and Tanker Reload Locations. For FMUs, applies management objectives as weights and other attributes.
- **Fire**: Generates the "fire input tables" that the optimizer needs, by combining historic weather and ignitions with behavior simulations.
- **Resources**: Captures the "catalog" of fire fighting resources, their capabilities, costs, a rules base for associated costs, and constraints.
- **Analysis Parameters**: Other inputs such as time slices and budget levels.
- **IA Optimization**: The core of the system, allocates resources to the fire inputs, for full suppression fires.
- **Use of Wildland Fire (UoWF)**: For UoWF and other fires outside of full suppression; applies a rules base to determine organization.
- **Reports**: Analysis and visualization of the resulting IA organizations.
- **National Database**: A network-accessible data store of selected analysis run inputs and results; a tabular and spatial data repository.

These are the "conceptual" subsystems, related to the business needs (*problem* space) of FPA PM. Other subsystems, such as administration, logic flow, and lower level frameworks, will be identified in the *solution* space of the Technical Architecture.

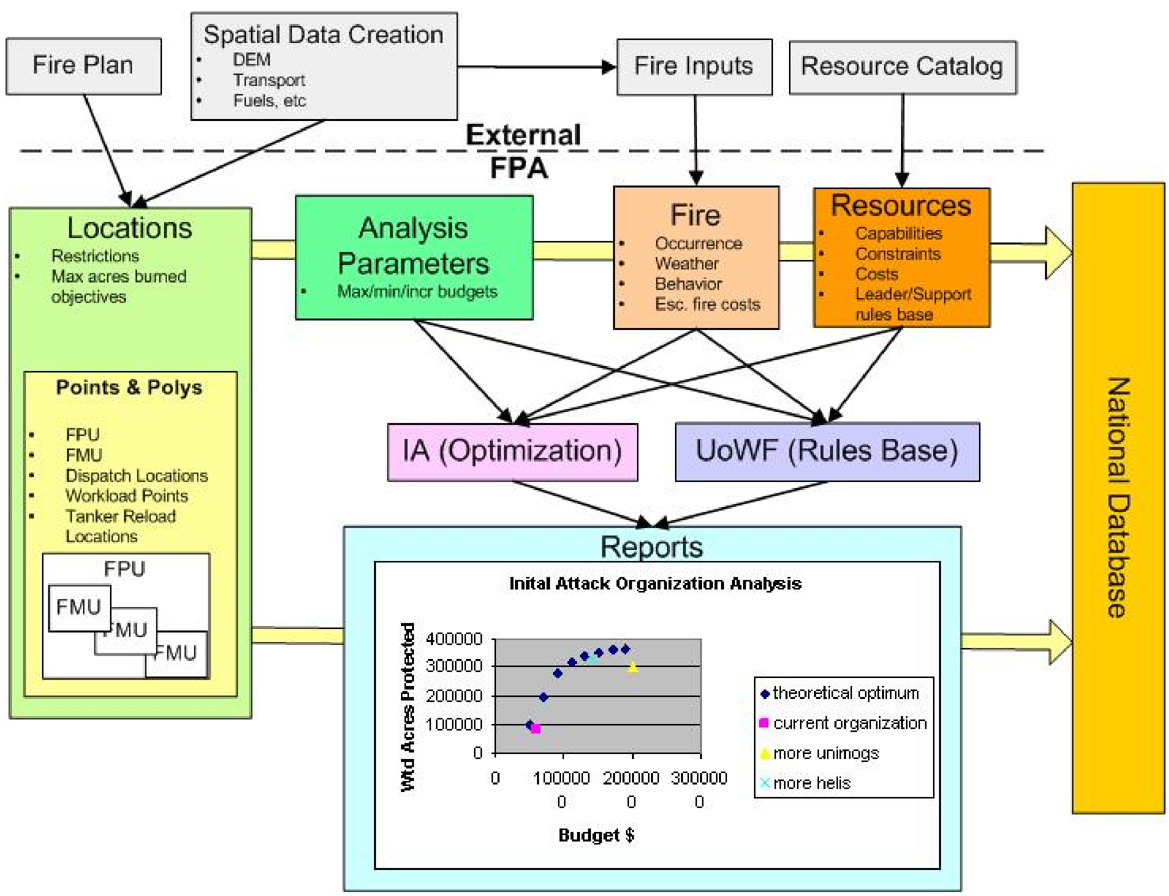


Figure 3 Top-level vision - FPA PM subsystems

This view of the system groups the components of the “cans and boxes” diagram (Appendix Cans and Boxes Diagram) into subsystems. The analysis that led to this structure occurred concurrently with the development of the Requirements Specification and Technical Architecture. Those documents capture (or will capture) many of the opportunities and limitations that led to this structure.

Each subsystem fulfills a role in the FPA PM. These responsibilities are illustrated in **Figure 4** FPA PM System Boundaries, subsystem-level, and described in greater detail in the following sections which cover each subsystem.

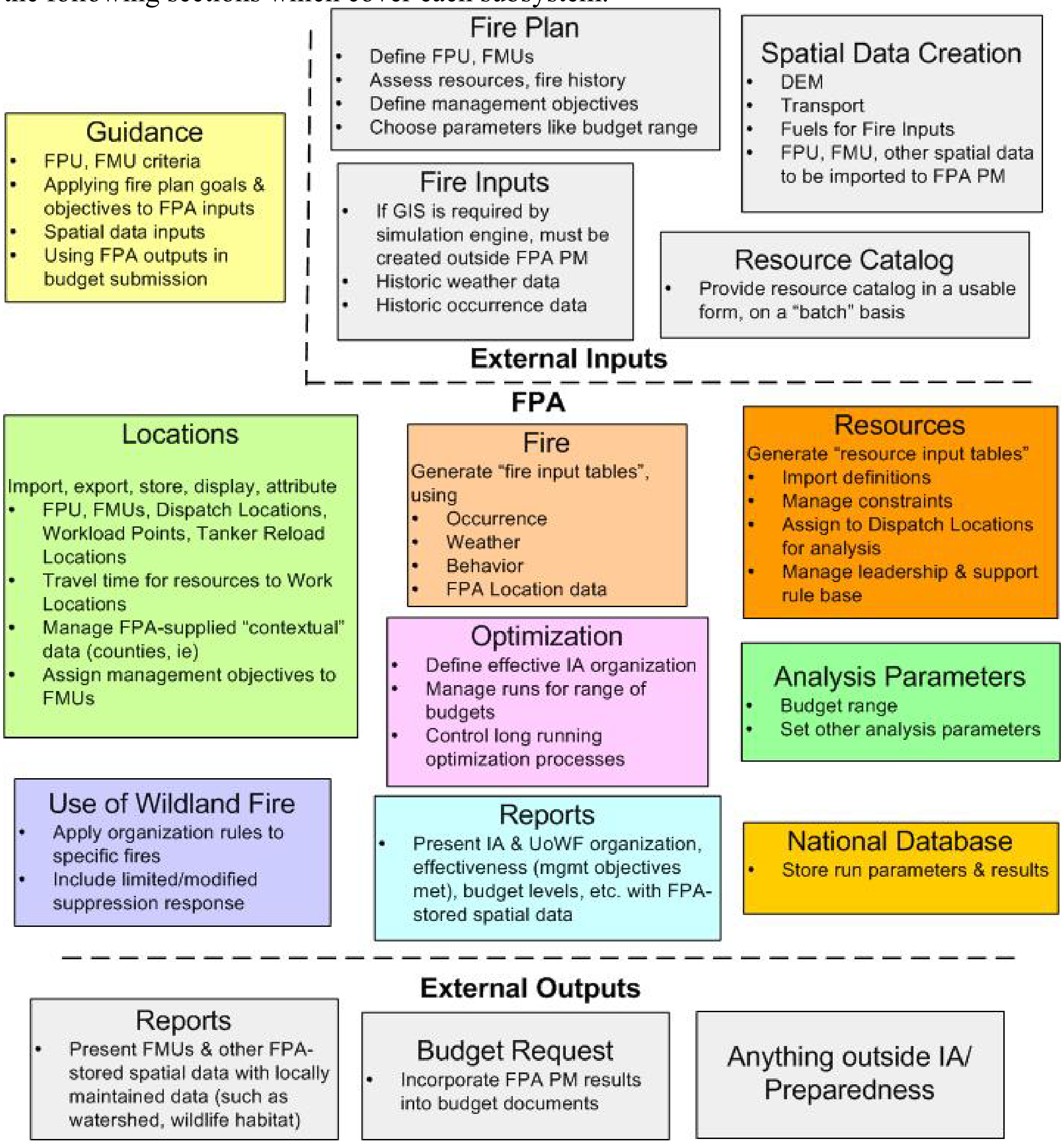


Figure 4 FPA PM System Boundaries, subsystem-level

3.1 Locations

Many elements of IA and Preparedness are intrinsically spatial. Fire behavior depends on fuels, weather, topography, ignitions, and more. Management objectives are set on an FMU - a piece of land. Resources are dispatched from locations. However, spatial data was originally outside the scope of the FPA PM. The team decided during meetings in Boulder on Jun 5-6, 2003, to require a particular level of spatial capability. This decision included consideration of an Issue document, an Assessment of alternatives, and analysis of the options.

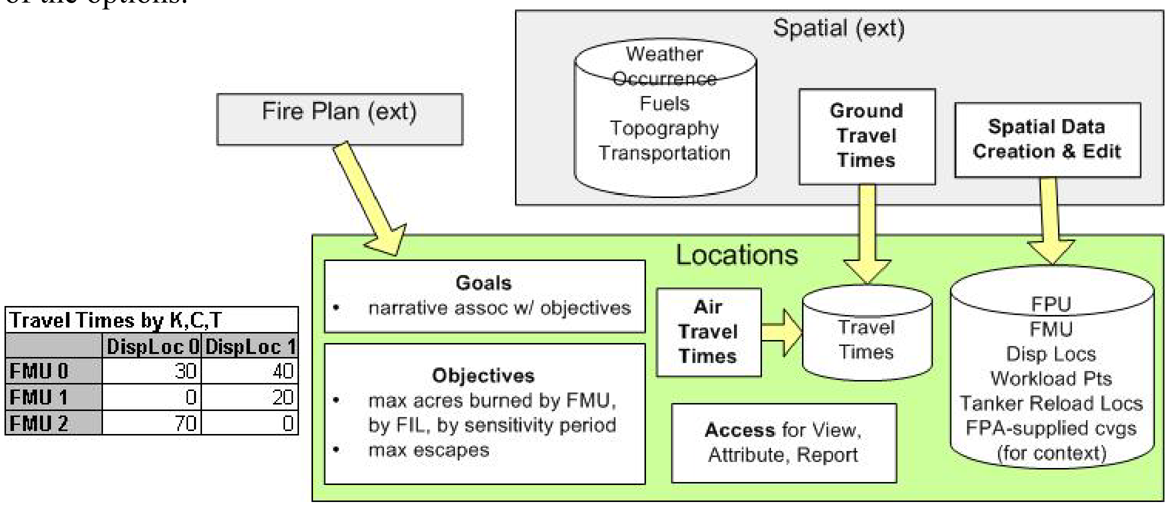


Figure 5 Spatial subsystem

The diagram above identifies which data processing and storage is inside or outside of the FPA PM's scope. The system will provide mechanisms to import the externally created data. It will also be able to export the spatial data, for use external to the FPA system. This view does not imply the physical deployment or distribution of an implementation - that is in the TA. Without jumping into too many TA details, the rationale for this structure includes:

- Locally created and maintained data is best kept in the local system. In this context, *local* does not necessarily imply the local PC; it means the local GIS *shop*, or more generally, whatever repository (local or corporate) is used by the office doing the planning. This data may be the *source* for *derived* FPA PM items, but this source is not intrinsically part of the FPA PM system. For example, FPUs and FMUs may be derived from arbitrary sets of local data, which may vary from FPU to FPU. One planner may use watersheds, another wildlife habitat.
- FPA PM *required* data is best kept in the FPA PM system, either PC or (preferably) server. This data is fundamental to assigning and reporting attributes, and to creating and understanding the optimization model inputs and outputs.
- Ground travel time calculations could be tabular, but spatial processing may require detailed local roads data. If this exists, it will be specific to the local office.
- Air travel time can be processed independently of local datasets. Non-tanker reload times will be manually entered.
- Workstation-based spatial data creation and editing tools (ESRI) are mature and have straightforward development environments. Web-based data creation and editing can be development-intensive and impose firewall limitations.

- Incorporation of (potentially) arbitrary numbers, types, and sizes of GIS datasets into the FPA system would introduce complex stewardship, storage, standards, network, and policy issues.

Restriction: *Term applied to FMUs, identifying limitations, such as "engines can't respond in a wilderness." See also – Resource constraints.*

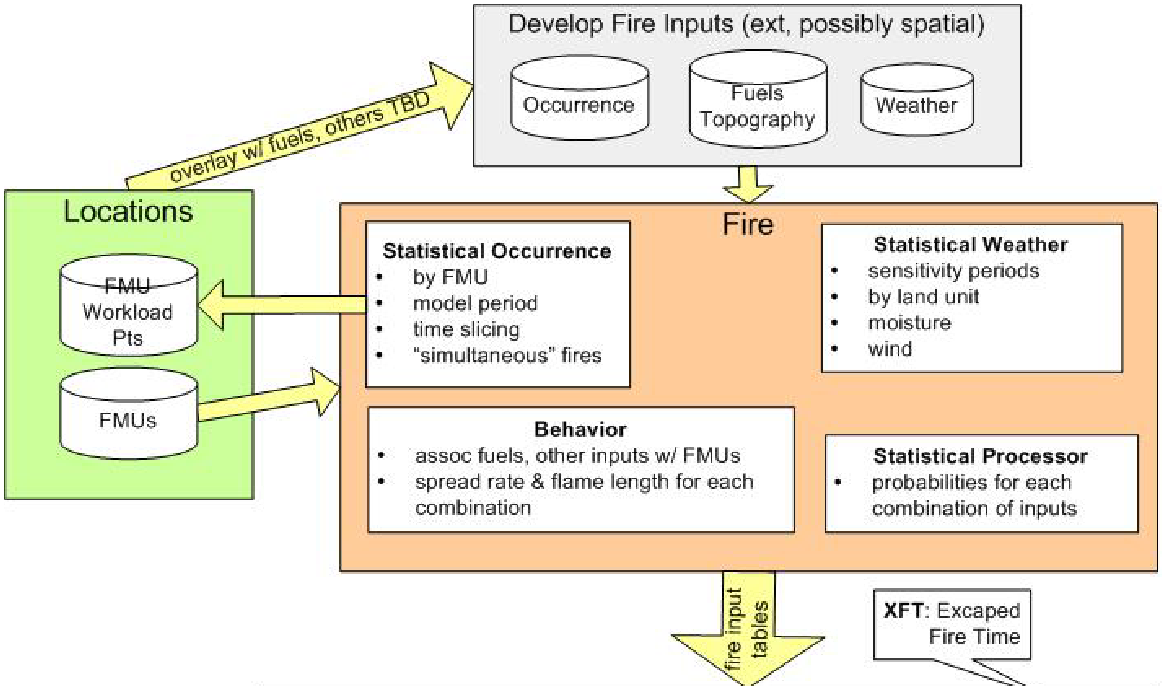
FPA PM is to be an "objective-driven" system. The Locations subsystem associates objectives, derived from management goals, with a piece of ground. In the Technical Architecture, these attributes may be managed independently of the spatial geometries. Conceptually, both apply to a piece of ground. The optimization model itself has a single objective: maximize weighted acres protected (WAP). The system associates weights with an FMU, for an FIL, for each sensitivity period. (In practice, these weights get associated with a fire event). The model considers these weights when assigning resources between competing fires, effectively mapping the coarse model objective (maximize total WAP) onto FMU-specific objectives.

3.2 Fire

Several approaches were considered to generate the "fire input tables" required by the optimization model, including: use historic fire ignitions, behavior, and costs; or create statistical profiles of historic weather and ignitions, combined with fuels, to simulate one or more "scenarios" of fires in a planning period. The FPA team and the Missoula Fire Lab have chosen the latter approach.

The Fire subsystem will

- Gather the historic data (occurrence, weather) from legacy databases.
- Use (or gather) fuel, topography, and other "static" inputs needed for behavior simulation.
- Create statistical profiles of probable fire events and behaviors.
- Associate the data with an FMU's "Workload Point" (WL, which may be derived from historic ignitions. NOTE this is an exception to the general rule that the FPA PM creates no spatial data).
- Generate the optimization model's "fire input tables".



FIRE INPUT TABLE - for each fire							XFT
index	1	2	3	4	...	T	
minutes	5	10	30	60	...	2880 (48 hrs)	
Perimeter	2	4	5	9	...	15	40
Area	0.25	1	1.5	5.1	...	14.3	101
Fire Cost	400	400	400	400		400	5000

Figure 6 Fire subsystem

3.3 Resources

The optimization model at the center of the FPA PM system requires "resource input tables". These tables are the result of processing that accounts for:

- **Time**: Travel, get away, reload, and other delays from each dispatch location to each fire event (workload point). A special case is retardant reload locations. Some of these may be derived from spatial data (air travel), some external to FPA (ground travel), and some entered manually based on local understanding (non-tanker reload).
- **Line production**: By Kind, Category, Type (KCT), and Fuel Model.
- **Costs**: Fixed and variable associated with resources.
- **Resources**: Existing and possible for use on a fire.
- **Constraints**: On those resources.

Constraint: *Term applied to Resources, identifying capabilities, such as "this engine can't operate in this Fuel Model". See also – FMU restrictions.*

Figure 7 Resources subsystem illustrates the Resource subsystem's functions and key interactions with internal and external systems.

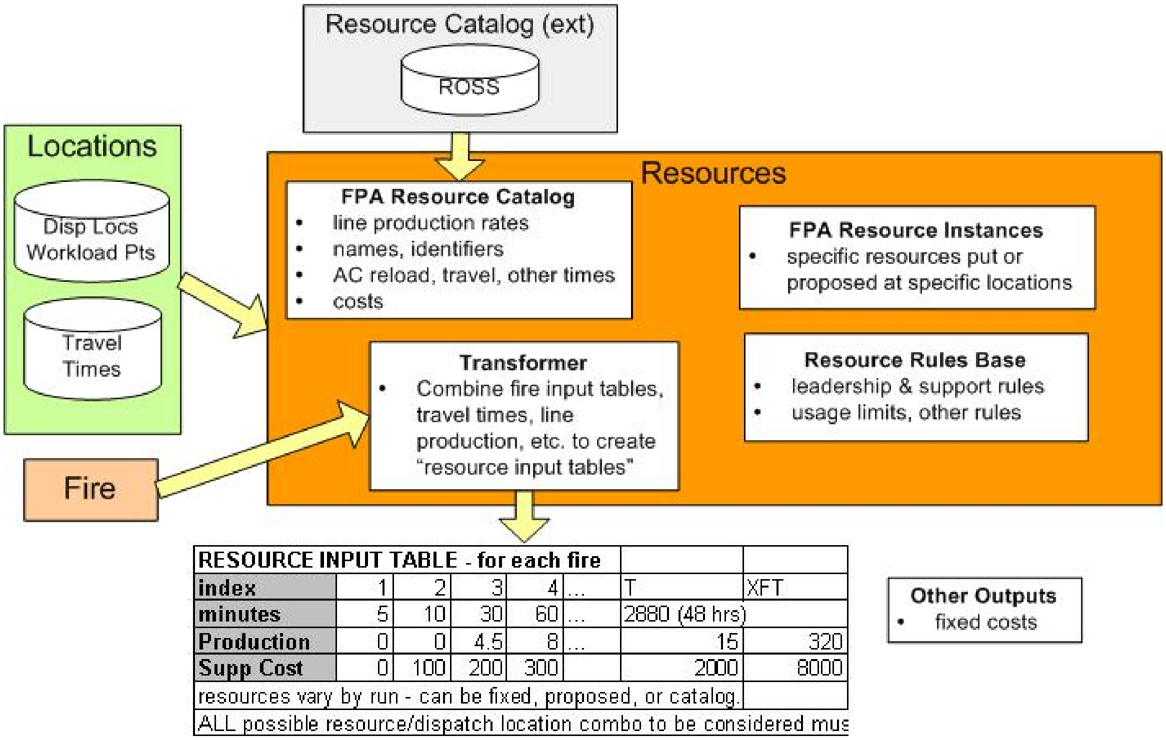


Figure 7 Resources subsystem

Using the Resources subsystem, the FPA PM administrator can import and manage a snapshot from ROSS to serve as the catalog. Users can then define resources for an analysis run, as described in section Optimization. It is important to clarify the difference between resource "classes" and "instances". This difference is analogous to the difference between "elk" (the species, or class) and "an elk" (a critter you can see, an instance of a class defined in the catalog). With that in mind, here are some essential definitions:

- **The Catalog**: Defines the Kind, Category, and Type (KCT) "classes". These are the *sorts* of resources that can be used, not the resources themselves.
- **Proposed (or User-Defined or Current or Selected or Existing) Resources**: The user can identify resource "instances" that the optimizer *should* use, so the model can reflect specific existing or proposed organizations.
- **Possible (or Catalog or Unconstrained) Resources**: The optimization model can freely "instantiate" (create an *instance* of a *class*) whatever resources can best meet the objectives.

3.4 Analysis Parameters

The Analysis Parameters subsystem manages other inputs and run parameters, as shown in the diagram.

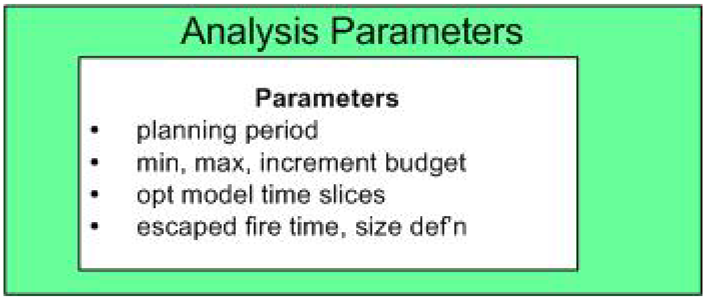


Figure 8 Analysis Parameters subsystem

These parameters do not come directly from an external system, but they will be influenced by the fire plan and budgeting process. Some parameters, such as optimization model time slices and escaped fire definitions, are essentially lookups, editable only by the FPA system administrator.

3.5 Optimization

The optimization model is described in Dr. Doug Rideout's (Colorado State University) original formulation and the Linear Programming (LP) Model Assessment paper. The model takes the inputs identified above, determines which resources optimally meet objectives (as represented by weighted acres protected (WAP)) for the budgets identified, and captures those results. The model has no understanding of spatial data or relationships. The input tables (via associated processing) capture the relevant impacts of the spatial relationships.

Some key issues are still being settled about the model:

- **Fire events**. Input fire events drive the model - these are "consumers" of resources. The events themselves can take one of several forms for the planning period (year):
  1. A single scenario of discrete fire events for the year. This was the original approach envisioned. It presumes that an effective IA organization can be planned based on a single, simulated, "representative" fire season.
  2. Multiple scenarios of discrete fire events, with associated probabilities of each scenario. This was to account for the unpredictability of fire seasons - a single fire scenario might not yield a realistic organization. The idea was to solve each scenario, and to accumulate the IA organization incrementally, based on the scenario's probability. This approach has been dismissed as non-optimizing.
  3. Stochastic modeling. Stochastic modeling accounts for uncertainty by considering multiple fire season scenarios and their associated probabilities within a single, optimizing framework. This is the preferred approach.

  The Technical Architecture will discuss whether options 2 and 3 are tractable.
- **Leadership and support rules base**. This applies overhead and other costs, based on the IA organization. Originally envisioned as a "post optimization" process, it was concluded that such an approach could lead to a sub-optimal solution. These rules will now probably be included in the optimization model.

For more on these and other model issues, see the LP Assessment paper.

The optimization itself will run within the context of a COTS solver engine. Such commercial products are designed to efficiently handle large, complex problems. The specific solver will be identified in the Technical Architecture, based on the COTS Solver white paper. Integration with a well-defined COTS interface leads to the following Optimization subsystem:

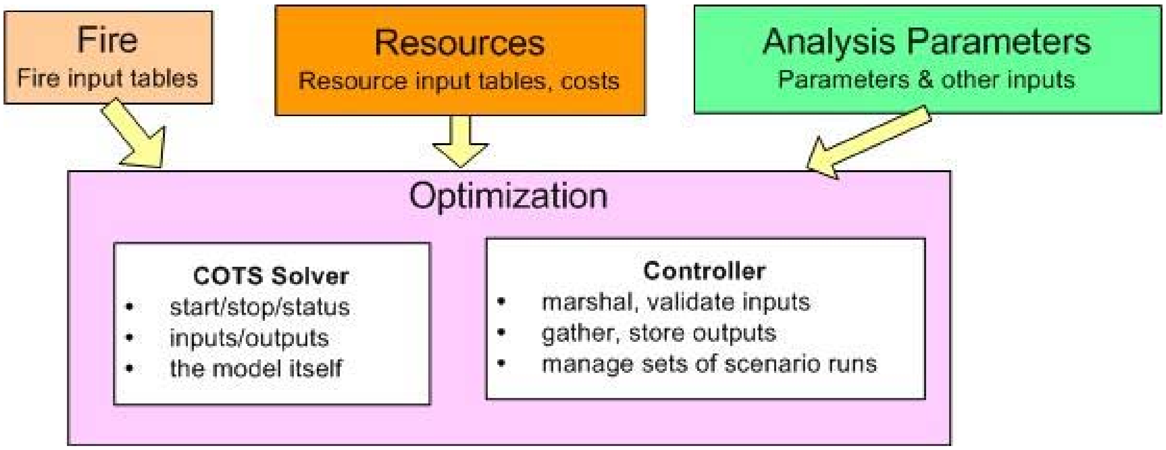


Figure 9 Optimization subsystem

The Controller provides a layer of separation between the COTS Solver and the rest of the FPA PM system. This approach will help insulate the optimization model from changes to the collaborating subsystems. (Note that this level of definition begins to identify Technical Architecture mechanisms).

An optimization "run" is a single fire year scenario (or stochastic set of scenarios), constrained to a single budget level or fixed set of resources. This corresponds to a single point on the graph in Figure 10 Mock-up Report. The resources used for a run can take several forms:

- **Unconstrained**. The run freely "chooses" resources from the catalog.
- **Selected**. The run only uses resources specifically identified by the planner.
- **Selected and unconstrained**. Combination of the first two. The user can identify "must use" resources, but the optimizer is free to choose other, additional resources from the catalog.

In practice, the planner will run the optimization model multiple times. Such analyses can include:

- **The "optimal frontier"**. Multiple runs for series of budget levels, using "unconstrained" resources.
- **"as is" organization**. A run using only "selected" resources that represent the current (or proposed) IA organization and budget. The result shows effectiveness for the planning fire scenario(s).
- **"what if" organization**. Uses "selected and unconstrained" resources, for single or multiple budget levels. This is useful for planners to identify resources they currently have (or are procuring), and to plan for additional resources identified by the model.

A budget submission might include one or more of these sets of runs. The documentation will provide guidelines on how to access and use the run results. The system will not restrict how its outputs are used in the budget request process - agencies will set and enforce these policies external to FPA PM.

3.6 Use of Wildland Fire (UoWF)

Recent discussions have identified UoWF as an important feature to include in the first release of FPA PM (see Issues in the Appendix). UoWF includes limited or modified suppression fires. Implementation is envisioned as follows:

1. Certain fires in a scenario are identified as “UoWF” or “limited response” fires
2. These fires are not sent to the optimization for IA modeling. They are sent to the UoWF rules base subsystem, which applies resources and costs based on those rules.
3. The results are joined with the IA Organization and budget results from the optimization

This is a very recent addition still being analyzed. See the Appendix Selected CA Issues.

3.7 Reports

The reporting subsystem will present the optimization results in a form that allows the planner to interpret the output of one or more analyses:

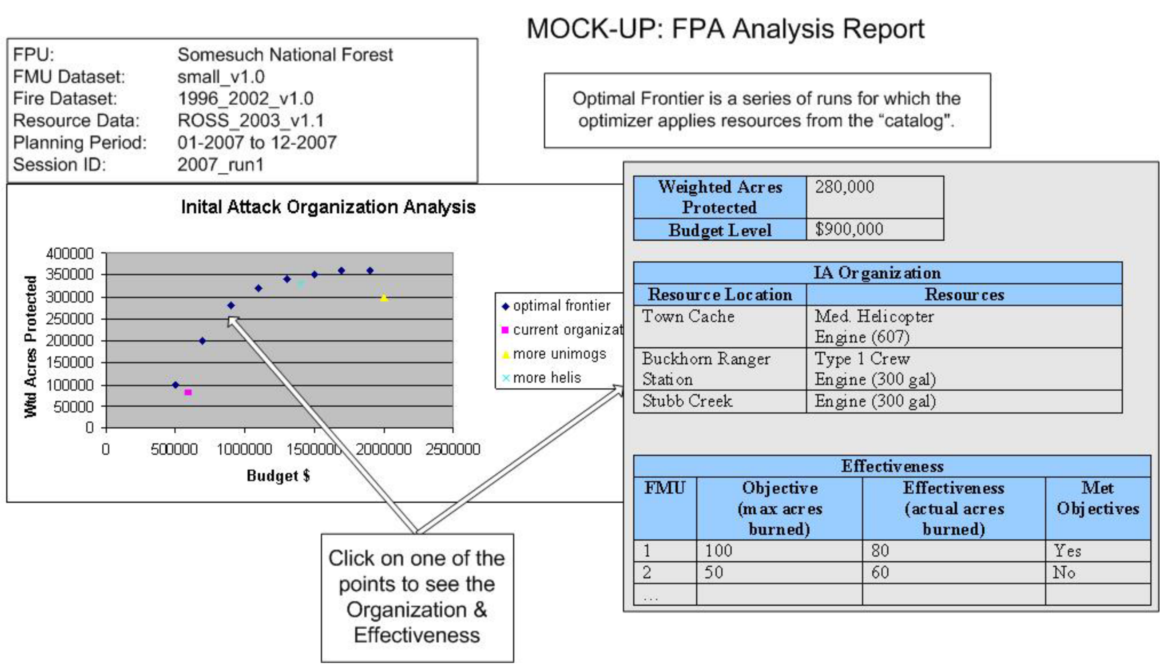


Figure 10 Mock-up Report

The following subsystem diagram presents a categorization of the types of reports. It does not define the system that will generate the reports. The TA will identify the mechanisms and frameworks (HTML, RDBMS, etc.) that support these reports.

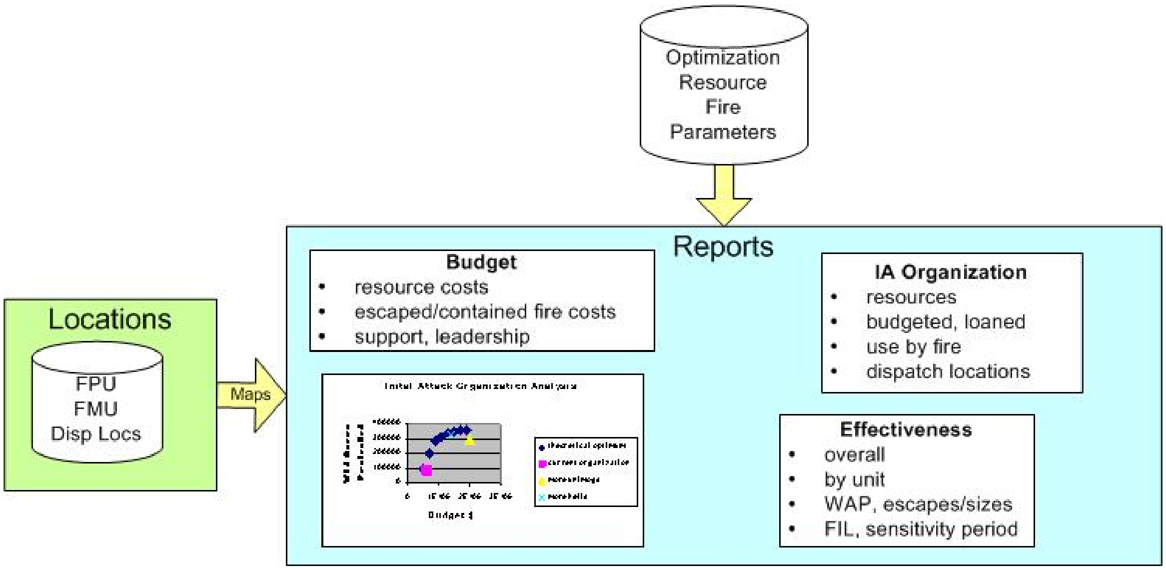


Figure 11 Reports subsystem

These reports will be network web-based. In addition to fire planners, users can include others involved in the planning and budget process. As discussed earlier, the outputs can be used and downloaded for inclusion in budgeting and planning documents. Tabular and map versions may be supported, depending on the requirements.

3.8 National Database

The National Database will store selected analysis run inputs and results in a network-accessible data store. This database will include tabular and spatial data, for future data warehousing or mining.

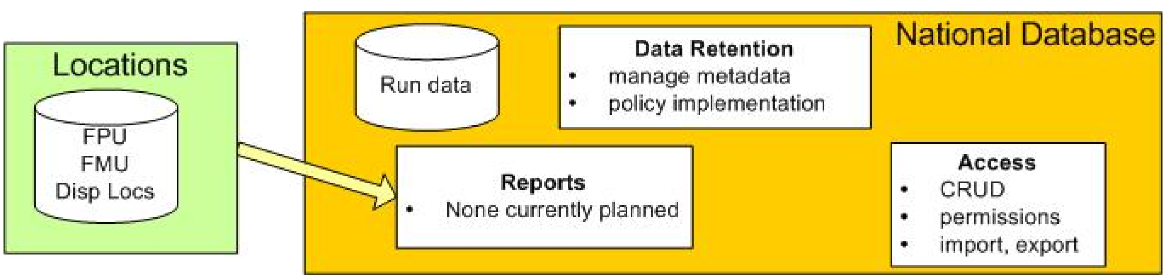


Figure 12 National Database subsystem

This database will support rollup reporting, inter-FPU collaboration, and some record retention requirements.

4 Summary

The external systems and internal subsystems described in this Conceptual Architecture capture the high-level view of the planned FPA PM.

The Technical Architecture will identify logical patterns, mechanisms, deployment views, and other implementation details that address *how* the team will develop the *what* of this document.

5 Appendices

5.1 Selected CA Issues

1. **GIS**. The role and scope of geospatial data (OUT: creation, editing; IN: attributing, display) was generally agreed to in meetings in Boulder on June 5-6. The RFP had envisioned a system designed to accommodate *future* GIS integration, but this document assumes that limited GIS (as identified) is now in scope. Local units must be capable of creating (or contracting creation of) the spatial datasets identified.
2. **Optimization**. The optimization model is not yet finalized. The most significant unresolved issue regards the inputs. The original plan had been to model a single set (“scenario”) of fire events for the planning period. Two alternatives include modeling a set of “scenarios” with associated probabilities, or developing a single stochastic model of multiple probable scenarios. The current approach is:
    a. Develop the single scenario model as a specific case of the stochastic model, that is, one scenario with probability of 1.
    b. After determining the tractability of multiple scenarios (probabilities sum to 1), implement as the general case.

    The team is assessing the sizing and performance implications.
    Many other issues are discussed in other project documents.
3. **Support and Leadership Rules Base**. Originally planned as a “post-optimization” process, there is a risk of selecting a “sub optimal” solution. As of 5/26/2003, we are studying the possibility and impacts of including these rules as an input to the optimization.
4. **Use of Wildland Fire**. The team is currently considering inclusion of a simple rules base to apply to fires that may fall under UoWF or “limited” suppression response. UoWF was out of scope in the RFP and FPA PM Charter, but has been reconsidered as important in this system. The proposed approach is:
    a. Separate UoWF fires from IA Fires
    b. Apply a rules base of work force needed to manage UoWF fires
    c. Merge with IA organization resulting from the (parallel) optimization

    There is a risk that the separation/rejoining of fires and resources may lead to a sub-optimal organization.
5. **Records Management**. The FPA system-stored data must be retained following appropriate policies. The system will not manage or enforce retention of data used to *derive* the system-stored data, but it will unambiguously identify such data sets. The user (or user’s unit) *should* save this data using guidelines appropriate for that data.
6. **Escaped fire costs**. Options for calculating these include:
    a. Use historical records.
    b. Calculate using resources within the model

See the FPA PM Issues document for a more exhaustive list.

5.2 References

- FPA PM Project Charter, November, 2002

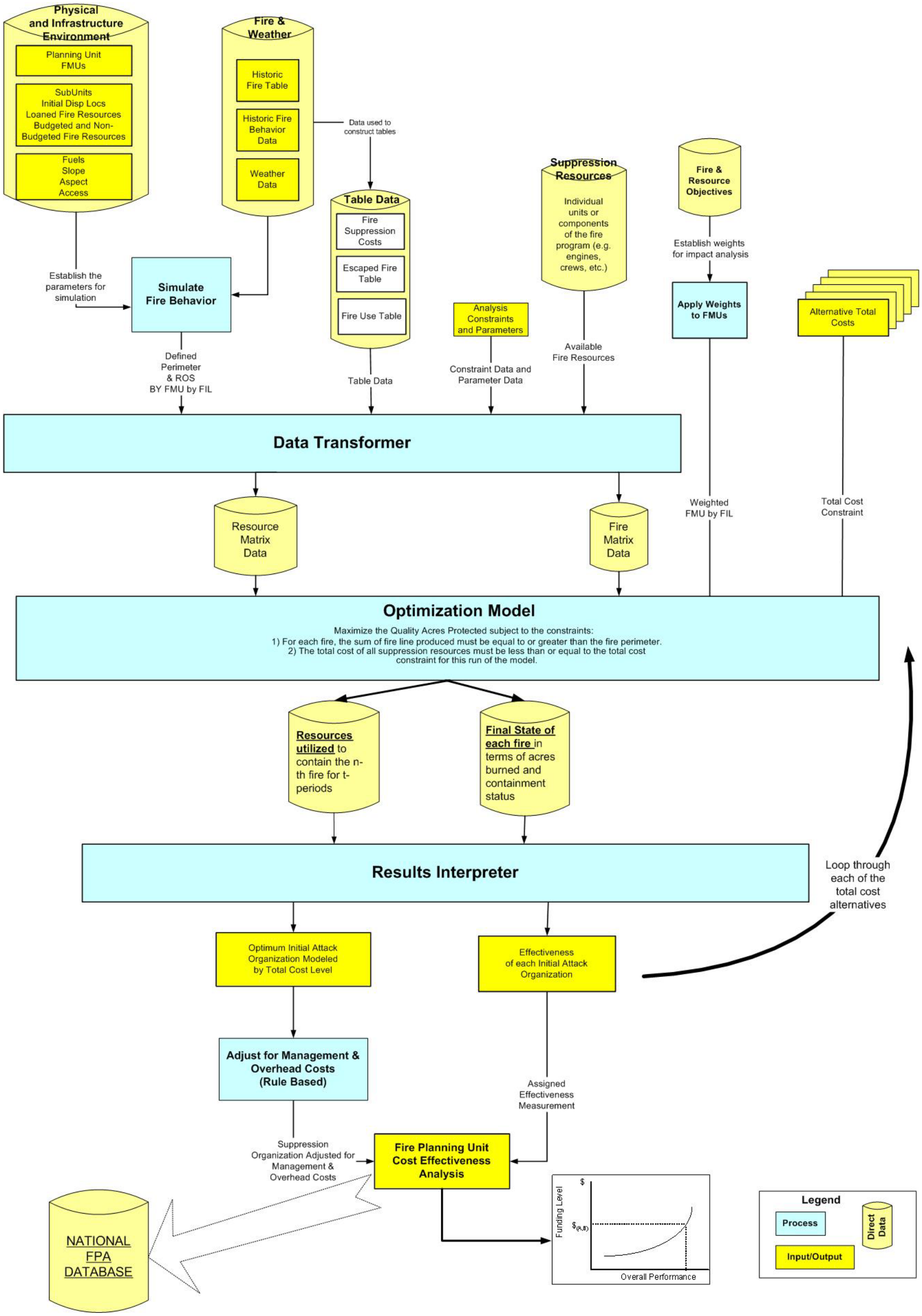
- Developing an Interagency, Landscape-scale Fire Planning Analysis and Budget Tool (the Hubbard Report), Report to the National Fire Plan Coordinators: U.S.D.A. Forest Service U.S. Department of the Interior
- Dr. Doug Rideout, Colorado State University, LP paper, FPA RFP, February, 2003
- FPM PM Requirements Specification, June, 2003
- Fire and Aviation Management Applications Summary spreadsheet filename "FAM Applications Summary V1.xls"
- Assessment of the potential role of geospatial data and processing - white paper, May, 2003
- FPA Spatial Capabilities - issue paper, May, 2003
- LP Model Assessment paper, June, 2003
- COTS Solver white paper, June, 2003

5.3 Meetings

- FPA kickoff meeting, Boise, May 12 – May 14, 2003
- Requirements meeting, Boise, May 19 – May 22, 2003. This meeting included user representatives from the Oregon, Alaska, and California "prototype" sites.
- Missoula Fire Lab FPA meeting, Boise, May 28-29, 2003
- Role and Scope of spatial processing meeting, Boulder, June 5-6, 2003.
- Requirements and Architecture working sessions, Boise, June 17-19, 2003. This meeting included prototype area representatives.

5.4 Cans and Boxes Diagram

The "cans and boxes" diagram from the RFP captures many of the important system components. This view represents a workflow, from the inputs, through optimization and analysis, to the results. Although some details have changed since the RFP, the view still captures many of the components presented in this document.


Physical and Infrastructure Environment
Planning Unit FMUs
SubUnits
Initial Disp Locs
Loaned Fire Resources
Budgeted and Non-Budgeted Fire Resources
Fuels
Slope
Aspect
Access
Fire & Weather
Historic Fire Table
Historic Fire Behavior Data
Weather Data
Data used to construct tables
Table Data
Fire Suppression Costs
Escaped Fire Table
Fire Use Table
Suppression Resources
Individual units or components of the fire program (e.g. engines, crews, etc.)
Fire & Resource Objectives
Establish weights for impact analysis
Apply Weights to FMUs
Alternative Total Costs
Establish the parameters for simulation
Simulate Fire Behavior
Analysis Constraints and Parameters
Defined Perimeter & ROS BY FMU by FIL
Table Data
Constraint Data and Parameter Data
Available Fire Resources
Data Transformer
Resource Matrix Data
Fire Matrix Data
Weighted FMU by FIL
Total Cost Constraint
Optimization Model
Maximize the Quality Acres Protected subject to the constraints:
1) For each fire, the sum of fire line produced must be equal to or greater than the fire perimeter.
2) The total cost of all suppression resources must be less than or equal to the total cost constraint for this run of the model.
Resources utilized to contain the n-th fire for t-periods
Final State of each fire in terms of acres burned and containment status
Results Interpreter
Loop through each of the total cost alternatives
Optimum Initial Attack Organization Modeled by Total Cost Level
Effectiveness of each Initial Attack Organization
Adjust for Management & Overhead Costs (Rule Based)
Assigned Effectiveness Measurement
Suppression Organization Adjusted for Management & Overhead Costs
Fire Planning Unit Cost Effectiveness Analysis
NATIONAL FPA DATABASE
Funding Level
$
Overall Performance
Legend
Process
Input/Output
Direct Data